Conservation of Mycodiversity in India: an Appraisal

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Introduction

Conservation of natural resources, both biotic and abiotic, was appreciated from the early dawn of civilization 5000–7000 years ago; it was even an essential part of some major religions, especially Buddhism and Jainism over two millennia ago. Tivy (1993) recorded that conservation of forest resources was official policy in China as early as the 3rd century BC. Indian civilization also has a long history of conservation ethics starting from the Vedic period. Conservation of biodiversity is ingrained in Indian history, culture, religion and philosophy. Existence of sacred forests in some parts of India is evidence of the Indian people's deep interest in conservation.

Conservation of biological diversity has been the subject of intense debate all over the world during the past two decades or so and is considered critical to the health and stability of the biosphere. It has been defined by the International Union for Conservation as human use of the biosphere so that it may yield the greatest sustainable benefit to the present generation while maintaining its potential to meet the needs and aspirations of the future.

Terrestrial biodiversity exists on earth in eight broad realms and 193 biogeographical provinces (Khoshoo, 1991). The distribution, however, is uneven; tropical and subtropical regions (mostly developing countries) are vastly richer than the temperate and polar regions (developed countries; Hawksworth, 1991); although tropical forests cover only 7% of the earth's land, they contain 50% of all species (McNeely *et al.*, 1990).

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The Indian Scene

The Indian subcontinent is a vast land mass covering 3,287,263 km^2 (Oxford School Atlas, 1993), lying between latitudes 8–37°N and longitudes 68–98°E (Fig. 10.1). The country has a coastline over 7516 km long (Khoshoo, 1996a). The altitude varies from sea level to 7817 m, and it is isolated from the rest of Asia by the mountain ranges of Himalaya in the north. The subcontinent falls into two out of eight proposed global realms, the Palaearctic and Indo Malayan realm and 12 biogeographical provinces according to one classification

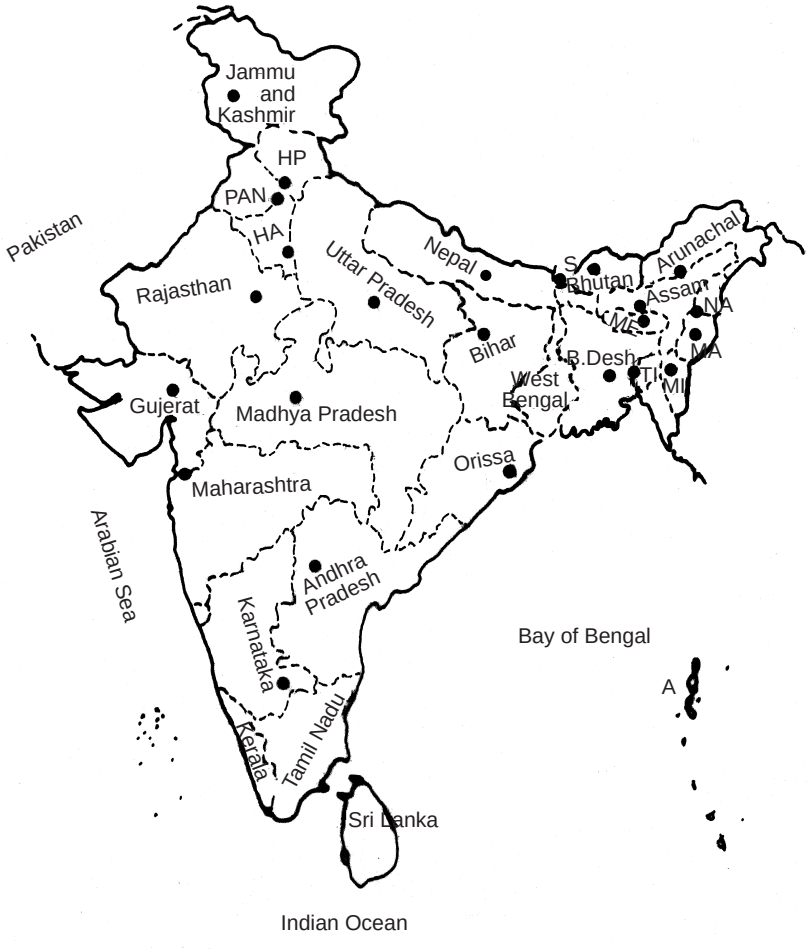

Fig. 10.1. Map showing location of various Indian states, union territories and adjacent countries. Abbreviations: A, Andaman and Nicobar islands; B, Desh, Bangla Desh; HA, Haryana; HP, Himachal Pradesh; MA, Manipur; ME, Meghalaya; MI, Mizoram; NA, Nagaland; PAN, Punjab; S, Sikkim; TI, Tripura.

(Khoshoo, 1996a). Khoshoo (1991) further identified six broad terrestrial ecosystem types in these provinces: tropical humid forest; tropical dry or deciduous forest (including monsoon forest or woodlands); warm deserts and semi deserts; cold winter (continental) deserts; mixed mountain and highland systems (with complex zonation); and mixed island systems. However, Rodgers and Panwar (1988), revising the earlier classifications, divided the Indian subcontinent into 10 biogeographical zones and 25 biotic provinces. These zones are: trans-Himalayan (Ladakh), Himalayan, desert, semi-desert, Western Ghats, Deccan plateau, gangetic plains, north-east India, islands and coasts (Khoshoo, 1996a). Champion and Seth (see World Wide Fund for Nature – India, 1992) recognized 16 major forest types with various subdivisions in India covering 63.8 Mha (19.4% of geographical area). Each type differs significantly from the others in structure and floristics.

The total number of living species recorded for India is presented in Table 10.1. Nearly 73% of India's bio-wealth consists of fungi (19.5%; including lichenized taxa), insects (40%) and angiosperms (13.5%). This tallies generally with the overall trend seen in the tropics and subtropics (Khoshoo, 1995). Although India has only 2.4% of the land area of the world as a whole, according to the present estimates, it hosts 8% of the global biodiversity.

Table 10.1. Biota of India (after Khoshoo, 1995).

	Number of species	Percentage
Bacteria	850	0.7
Algae	2,500	2.0
Fungi (non-lichenized taxa)	23,000[a]	18.2
Fungi (lichenized taxa)	1,600	1.3
Bryophyta	2,700	2.1
Pteridophyta	1,022	0.8
Gymnosperms	64	0.1
Angiosperms	17,000	13.5
Protozoa	2,577	2.0
Mollusca	5,042	4.0
Crustacea	2,970	2.4
Insecta	50,717	40.0
Other invertebrates including Hemichordata	11,252	9.0
Protochordata	116	0.1
Pisces	2,546	2.0
Amphibia	204	0.2
Reptilia	428	0.3
Aves	1,228	1.0
Mammalia	372	0.3
Total	126,188	100.0

[a]Varma and Sarbhoy (1996) estimated the number of known species in India to be *c*. 24,000.

Geographically four main regions have been defined in the subcontinent. These are: the Himalaya, the Indo-gangetic plain, the Indian desert and Deccan plateau. In view of the importance of vascular plants in any assessment of macrofungal diversity, the vegetational patterns and climatic diversity of these areas are summarized.

The Himalaya

The Himalaya represents the highest mountain system in the world extending across northern India from west to east, it is 2500 km long, occupying an area of 236,000 km^2. It extends from the Indian plains to the Tibetan Highlands in four almost parallel ranges from south to north. These are: the outer Himalaya or Siwalik range, the middle or lesser Himalaya, the inner or great Himalaya and the trans-Himalayan region.

The western and eastern flanks of the Himalaya differ. The western Himalayan ranges are much wider and colder with a drier climate. In contrast, the eastern ranges are among the wettest regions of the world with great biodiversity (Khoshoo, 1996b). The western ranges have a vegetation which is drought resistant. There are large populations of conifers such as the chir and blue pine, deodar, fir and spruce. On the other hand, in the east, conifers though present are not a dominant element. *Rhododendron* dominates the plant life of this region. The eastern ranges receive the full thrust of monsoon winds from the Bay of Bengal and contain a large number of epiphytes, and a profusion of orchids, tree ferns, oaks, magnolias and gymnosperms not found in western Himalaya: *Larix*, *Tsuga dumosa*, *Podocarpus* and *Gnetum*. Sixty-three species of bamboo are also found in this region, there being very few in western Himalaya.

Khoshoo (1992) describes the forest types found in both regions. In western Himalaya the vegetation can be distinguished into six different types: tropical deciduous forests, subtropical pine forests, Himalayan moist temperate forests, Himalayan dry temperate, subalpine forests, and alpine pastures and scrub.

In the eastern Himalaya, which is a region of high monsoon intensity with a humid climate, the vegetation types are: tropical evergreen forests, subtropical forests, eastern temperate forests, alpine vegetation, and stony deserts.

The Indo-gangetic plain

The Indo-gangetic plain covers 643,700 km^2 formed by the river basins of the Indus, Ganges and Brahmaputra (Manjula, 1983). This area is largely tropical, with a mean annual temperature of 26°C. Much of the region has a high rainfall. In Assam, a tropical rainforest vegetation exists, elements of which are shown to have affinities with the forests of Kerala in the far south. The Indo-

gangetic plain is an area of high population and extensive cultivation, so little collecting of fleshy fungi has been undertaken apart from in Assam and the Calcutta region of West Bengal.

The Indian desert

The Indian desert is a region to the north-west of India covering Rajasthan and has minimal rainfall and few macrofungi.

The Deccan plateau

The Deccan plateau is the oldest land mass in India (Manjula, 1983). In the north it is bounded by the Vindhya mountains with an altitudinal range of 450–1200 m and is separated from the Arabian Sea Coast and Bay of Bengal Coast by the Western Ghats and Eastern Ghats respectively. The ghats have an altitudinal range of *c*. 500–650 m. The Western and Eastern Ghats meet at Nilgiri Hills in Tamil Nadu State, and in the areas of highest elevation a sub-temperate mycobiota is to be found. A major part of the Indian subcontinent is, however, governed by the tropical monsoon and the plains of southern India experience periods of high temperature and humidity with a mycobiota associated with that climate.

Conservation Initiatives

Despite compassion for all life, ingrained in the psyche of most Indians from childhood, considerable loss of biodiversity, especially wild animal life, has occurred in India. However, recently, a move to conserve biodiversity has started, although microbial biodiversity still receives low priority.

For any meaningful conservation programme the following steps are essential. First, an assessment of biodiversity has to be made, together with a study of changes over a specified period. Subsequently, lists of threatened or extinct species should be compiled (Red Data Lists). In the final phase, conservation measures, both *in situ* and *ex situ*, have to be drawn up and implemented.

The main agencies for assessment of biodiversity in India are the Botanical Survey of India (established in 1880) and the Zoological Survey of India (established in 1916). Other institutions involved in ecological surveys and research are: the Forest Research Institute, Dehra Dun; the Wild Life Institute of India, Dehra Dun; the Gobind Ballabh Pant Institute of Himalayan Environment and Development at Almora (UP), and the National Environment Engineering Research Institute at Nagpur. Besides the above, institutional support in this activity also comes from universities (both agricultural and traditional) and

national institutes, including the Indian Agricultural Research Institute, New Delhi, and the Indian Institute of Science, Bangalore. The Ministry of Environment and Forests recently established by the Government of India can be considered to be a 'nodal' agency for conservation measures.

Among the non-governmental agencies, the World Wide Fund for Nature–India (WWF–India), established in 1969, is the country's largest conservation agency. Other non-governmental organizations involved in promoting nature conservation in India are: the Bombay Natural History Society; the Indian National Trust for Art and Cultural Heritage (INTACH); the Centre for Environmental Education (CEE); the Centre for Science and Environment (CSE); and Development Alternatives (World Wide Fund for Nature–India, 1992).

Both *in situ* and *ex situ* measures currently operate in India to conserve biodiversity. Among the *in situ* measures are the development of a network of protected areas, including biosphere reserves, national parks and sanctuaries. Since the Wild Life (Protection) Act 1972, their number increased to 66 national parks and 421 sanctuaries by 1990, covering around 4% of the country's geographical area (World Wide Fund for Nature-India, 1992). Seven biosphere reserves had also been notified by 1991 (Khoshoo, 1991). *Ex situ* conservation is achieved by field gene banks, seed and other banks, botanical gardens and zoological parks. The situation regarding biodiversity conservation in Himalaya is discussed in detail by Khoshoo (1996b).

Among 17,000 species of flowering plants in India, 6850 (40%) are endemic to India, with *c*. 50% in the Himalaya (see Khoshoo, 1966b). Endemic flora and fauna assume great importance in determining priorities for conservation.

Macromycetes

The overall conservation activities in India have been summarized and are followed here by a résumé of the mycobiotic situation.

Conservation studies on fungal diversity are a recent development on the world scene, having started in the 1980s, although recording of fungi was started as early as 1729 by Micheli. Attention has been mainly devoted to macrofungi, commonly known as mushrooms. Watling (1990) observed that the chances of producing a Red Data List for microfungi are practically nil.

Fungal diversity is often assumed to be like biodiversity in general in tending to be greater in the tropics and subtropics than at higher latitudes (Lodge, 1997). Presently, only 4.6% of the world's estimated fungi are known and most of these are from temperate regions of the world (Hawksworth, 1991). Coddington (see Sarbhoy, 1997) considered that more than 20–40% of the tropical fungi are undescribed, but tropical forest ecosystems are undergoing massive annual losses.

History

There are references to the use of mushrooms as food and medicine in India in the ancient medical treatise, Charaka Samhita (3000 ± 500 BC). However, their scientific study is of recent origin. It can be said to have started with the identification and description of *Podaxis pistillaris* (L.: Pers.) Morse by Linnaeus in the 18th century from a collection sent to him by Koening from Tamil Nadu State. A subsequent collection made by Sir J.D. Hooker, mostly from Assam, Darjeeling, Sikkim and Khasi hills, led to the publication of a series of papers by an English mycologist, the Revd M.J. Berkeley between 1850 and 1882 (see Natarajan, 1995).

Collection and scientific study of larger fungi from India have been divided into three phases. The first phase lasted from 1825 to 1899 and, in addition to Berkeley and Montagne, recorders during this phase included Fries, Léveillé, Currey, Cooke, Massee, Watt and Lloyd (Sathe, 1979; Natarajan, 1995).

The second phase (1900–1969) started with Paul Henning's significant contribution in 1900 and 1901, describing another 32 genera and 68 species (Natarajan, 1995). A significant feature of the second phase was the involvement, besides European and American workers, of a number of Indian workers in research on larger fungi (Sathe, 1979). Special mention should be made of the work on Indian fungi by E.J. Butler at Pusa (Bihar) in the post of Imperial Mycologist. His efforts led to the production of the first authoritative list, *Fungi of India*, in collaboration with G.R. Bisby (Butler and Bisby, 1931). This publication has been continuously updated until the latest edition by Sarbhoy *et al.* (1996). Among the Indian workers of this period were Professor S.R. Bose (Calcutta, West Bengal) and Professor K.S. Thind (Punjab University, Chandigarh). The third phase of the work, which is continuing, can be said to have started in the early 1970s with the development of an edible mushroom industry in India, providing much needed impetus.

Manjula (1983) critically examined all agaricoid and boletoid records from India and Nepal housed in the Kew Herbarium, UK, and listed 538 valid species attributed to 115 genera and 20 families. This provided a baseline for subsequent assessment of agaric resources of these countries. Watling and Abraham (1992) put the total of agarics in India at *c*. 650 species. However, Sarbhoy (1997) observed that, whereas 450 mushroom species (*Agaricales*) had been reported by 1977, a similar number has been added either to regional or Indian subcontinent lists of mushrooms during the last decade, taking the total to *c*. 900. Watling (1978) and Watling and Gregory (1980), comparing it with British agaric records, considered this to be too low a figure.

Identification and description of fungi have been carried out in the past in a number of Indian universities (both traditional and agricultural), and in research institutes mainly under the auspices of the Indian Council of Agricultural Research (ICAR) and the Council of Scientific and Industrial Research (CSIR). A national effort at assessment of fungal diversity and conse-

quent conservation measures was made with the development of an Advanced Centre for Biosystematics (Microbes and Invertebrates, ACBS) at the Indian Agricultural Research Institute (IARI), New Delhi in June 1993 (Varma and Sarbhoy, 1996). This centre has collaborated with the Commonwealth Agricultural Bureaux International (CABI). The ACBS is also developing an Indian Biosystematics Network (IBNET) which will foster links with biosystematics centres within various universities, ICAR Institutes and CSIR Institutes. The country also plans to establish a national Bureau of Agricultural Microorganisms which is expected to help in conserving biodiversity.

Current position at various Indian centres

Eastern Himalayan region

This region includes Eastern Himalaya proper and north-eastern hilly areas. The former includes the northern tip of West Bengal, northern parts of Assam, the whole of Arunachal Pradesh and Sikkim, and the latter the hilly states of Nagaland, Meghalaya, Manipur, Mizoram and Tripura (Khoshoo, 1992). Myers (1988, 1990, cited in Khoshoo, 1996a) listed 18 areas globally requiring special conservation efforts and designated them as 'hot spots'. Among these, two are in India, Eastern Himalaya and Western Ghats.

The first step in conserving the macrofungal diversity of a region would be the monitoring of mushroom species. Some efforts in this direction were made by groups working at Punjab University, Chandigarh, under the leadership of Professor K.S. Thind and Dr R.N. Verma and his associates at the Indian Council of Agriculture Complex in the north-eastern hill region at Shillong, established in the 1980s.

Sharma and Sidhu (1991) from Punjab University reported on the occurrence and distribution of the *Geoglossaceae* in the eastern Himalayan ranges of India. They maintained that the Himalaya in general and Eastern Himalaya and adjoining hills in particular are relatively rich in *Geoglossaceae*. They surveyed localities in and around West Bengal, Meghalaya, Assam and Arunachal Pradesh states and recorded 12 species distributed among nine genera: *Cudonia*, *Leotia*, *Maasoglossum*, *Microglossum*, *Mitrula*, *Thuemenidium*, *Spathularia*, *Trichoglossum* and *Geoglossum* with ecological notes. Two endemic species, *Maasoglossum verrucosporum* Thind & R. Sharma and *Mitrula agharkarii* Banerjee from the Himalayan range were also recorded by them. In India as a whole, the family is represented by 48 species within nine genera.

Thind and his associates have also worked on clavarioid homobasidiomycetes in the Himalaya, recording 181 taxa in 20 genera from Indo-Himalaya (Thind, 1961; Kaul, 1992). Sharda (1991) provided an updated check-list of these fungi with notes on their distribution. Genera reported from India included: *Amylaria*, *Clavariadelphus*, *Clavaria*, *Pterula* and *Ramaria*. In addi-

tion, Rattan and Khurana (1978) also published 'The Clavarias of Sikkim Himalaya'. Khoshoo, (1996b) concluded from Thind's researches that Himalaya was a major centre of diversity for higher fungi.

Verma *et al.* (1995) recorded the results of a macrofungal survey of the north-eastern hills (NEH), *c.* 8% of the country's total area, which can be divided into well-defined zones. These workers covered 102 locations in 24 districts of seven states including Sikkim and listed the species with ecological notes. Ninety-five species of larger fungi were determined and confirmed at the Kew Herbarium. Among these, 85 species were new records for the NEH region and 16 for India.

Lakhanpal (1993) comprehensively reviewed Himalayan *Agaricales*, listing all genera by family, and the number of species present in India and their distribution in both north-western and eastern Himalaya. Some genera were recorded only from Eastern Himalaya by one or more species, including *Cystoderma amianthinum* (Scop.: Fr.) Fayod, *Phaeogyroporus fragicolor* (Berk.) Horak, *Phylloporus pinguis* (Hook.) Singer, *Phylloporus sulphureus* (Berk.) Singer, *Tylopilus areolatus* (Berk.) Manjula, *Rhodocybe villosa* Horak and *Simocybe descedens* (Berk.) Manjula.

Mention should be made of the existence of sacred forests in Eastern Himalaya at Meghalaya (Khasi and Jainta Hills) and La Lygdoh at Mawsmai (Mawphlong and La Kyntok) near Cherapunji (Khoshoo, 1996b). These forests have been conserved over the ages on account of religious beliefs and have been left undisturbed, so diversity in these forests is unparalleled. Besides the angiosperm flora, rare species of macrofungi can also be expected. Bhagwat *et al.* (2000) presented relevant research in a poster session at the Liverpool Symposium on macrofungal diversity in three forested land use types including sacred groves in the Western Ghats of India. This showed that sacred groves contained the largest number of unique morphotypes whereas the forest reserve had none, suggesting their potential for conservation of macrofungal diversity in the Western Ghats of India.

Western Ghats (Kerala and Maharashtra)

The Western Ghats, another 'hot spot' in India, is considered to be South Asia's last remaining tropical rainforest. Sathe (1980) described it as a flange of a high mountain range running along the western coast from Tapti Valley in the north to Cape Comorin in the south, with a total length of 1600 km and average elevation of 1000–1300 m with high peaks rising over 2400 m. It extends to three states of India, Maharashtra, Karnataka and Kerala.

Kerala's Western Ghats cover an area of approximately 20,000 km^2 and are the biologically richest tracts. The Western Ghats have an endemic higher plant flora of 1600 species (Khoshoo, 1994), and rank in importance equal to Eastern Himalaya for conservation initiatives.

According to Natarajan (1995), the entire region of southern India, comprising the four states of Tamil Nadu, Kerala, Karnataka and Andhra Pradesh, was neglected as regards studies on agarics until 1975. Natarajan (see Kaul, 1992) listed 115 species from Kerala, and a macrofungal survey of the area was carried out at the Plant Pathology Department of Kerala Agricultural University at Vellayani, Thiruvananthapuram, by Ms Bhavani Devi from 1985 to 1988. The collections were made from 12 agroclimatic zones in four monsoon seasons and revealed the presence of 134 species of mushrooms (including 14 gasteromycete species) belonging to 45 genera (Bhavani Devi, 1995). Analysing these findings, the macrofungi of Kerala were broadly grouped into pre-monsoon, monsoon and post-monsoon elements. The pre-monsoon fungi included species of *Agaricus*, *Coprinus*, *Lepiota*, *Leucocoprinus*, *Psathyrella*, *Mycena*, *Agrocybe* and *Boletus*. The monsoon element consisted of *Cortinarius*, *Schizophyllum*, *Marasmius* and *Pleurotus* whereas species of *Cortinarius*, *Pleurotus* and *Termitomyces* occurred post monsoon. Very few collections were made 30 days after the monsoon period. Edible fruit bodies included species of *Termitomyces*, *Volvariella*, *Pleurotus*, *Macrolepiota*, *Boletus* and *Calvatia*. *Tuber magnatum* Vitt. (*Ascomycotina*), a highly prized truffle, is regularly collected and consumed by tribal people in the forest area of the southern part of this state.

Staff at the Botany Department of Calicut University and the Tropical Botanic Garden and Research Institute at Thiruvananthapuram are also surveying macrofungi, but it is evident that assessment of the macromycetes of the region is at only a preliminary stage.

Mushroom recording in Maharashtra was neglected for a long time and only 21 species of agarics had been recorded from the state by 1967 (Kamat *et al.*, 1971). Intensive work in the region only began after 1974 when A.V. Sathe and his group, working at the Maharashtra Association for Cultivation of Sciences, published a series of papers mainly on *Agaricales* (Sathe and Rahalkar, 1978; Sathe, 1979; Sathe and Deshpande, 1979, 1980; Sathe and Kulkarni, 1987). A comprehensive list of 231 mushrooms recorded from all regions of Maharashtra state was published by Patil *et al.* (1995).

North-west Himalaya (Kashmir, Punjab and Chandigarh Union Territory and Himachal Pradesh)

Khoshoo (1991) identified 26 'hot spots' in India and maintained that the Himalayan belt as a whole constituted one 'mega-hot spot'. North-western Himalaya has been the centre of intensive research on larger fungi since the 1950s.

Berkeley in 1876 (see Watling and Gregory, 1980) was probably the first to report larger fungi from the Kashmir valley. Although fragmentary recording was made from time to time, a serious effort was initiated by the author and his group in the late 1960s, working at the Regional Research Laboratory, Srinagar,

Kashmir. Sustained work carried out by Kaul, Kachroo and Abraham for over two decades resulted in the recording of 262 larger fungi from the region, among which 226 taxa were agarics (Abraham, 1991). A significant contribution to this study was made by Professor Watling from Edinburgh, UK, who, besides providing constant guidance to these workers, published a list of 119 species of larger fungi from the area, based on his personal collection (Watling and Gregory, 1980).

There are two active centres of research on macrofungi in this region and collections have mostly been made from North-west Himalaya. The first centre, at Punjab University, Chandigarh, led by Professor K.S. Thind, produced a series of papers on operculate discomycetes, particularly *Pezizales*. A total of 226 operculate discomycetes have been recorded from India so far; the major contribution from Thind and his associates.

Kaushal (1991), from the same group, has made a systematic study of North-west Himalayan species of *Helvella* and recorded 11 species from this region. Detailed descriptive and mycoecological notes on eight species were included. Thind and his colleagues have also published a series of papers on the *Polyporaceae* of India, and Thind (1973) reviewed the status of aphyllophoroid taxa in India. Later Rattan (1977) recorded 198 species of resupinate aphyllophoroid taxa from North-west Himalaya and Rawla and Arya (1987) recorded five agarics from northern India.

Another centre involved is the Botany Department, Punjabi University, Patiala. Saini *et al.* (1988, 1989) and Atri *et al.* (1991a) have described many species of *Russula* and *Lactarius*. Atri *et al.* (1991b) contributed a paper on systematic studies of *Agaricus campestris* (L.) Fr., and Atri and Saini (1989) reviewed work on the *Russulaceae* worldwide including the Indian components. To date only 81 taxa (55 of *Russula* and 26 of *Lactarius*) have been recorded from India.

Three important centres of work on macrofungi in the state are: The Biosciences Department, University of Himachal Pradesh, Shimla; the Agricultural and Horticultural University, Solan, and the National Research Centre on Mushroom (ICAR), Solan. Professor Lakhanpal, working at the University of Himachal Pradesh, Shimla, has made a major contribution with a list of 190 species of *Agaricales* occurring over the entire North-west Himalayan region (Lakhanpal,1995). His list, however, was restricted to *Agaricales* only and he did not catalogue species recorded before 1982 that had been published by Manjula (1983).

South India

Natarajan started work at the Centre of Advanced Studies in Botany, University of Madras in 1975 and his group has been collecting from the entire southern and south-western region. They started a series entitled 'South Indian

Agaricales', publishing over two dozen papers. Natarajan (1995) presented a list of 230 agaric and bolete species distributed among 67 genera from southern Indian states excluding Kerala.

Indo-gangetic Plains (Punjab, Uttar Pradesh and Bengal)

These plains are distributed over a number of Indian states: Punjab, Haryana, Delhi, Uttar Pradesh, Madhya Pradesh, Bihar, Orissa, West Bengal and Assam, but there has been limited activity as regards the scientific study of macrofungi in this region. Mention, however, can be made of the contribution by some individuals or small groups.

Two groups, working at Punjabi University, Patiala and Punjab University, Chandigarh (referred to earlier), have been active in the study of macrofungi in the plains of Punjab. Saini and Atri (1995) listed 94 species in > 24 genera belonging to the *Agaricales* and gasteromycetes. Prominent genera were: *Morchella*, *Agaricus*, *Agrocybe*, *Conocybe*, *Coprinus*, *Bolbitius*, *Pleurotus*, *Lycoperdon* and *Calvatia*. They also stated that the overall picture as far as the mushrooms of Punjab were concerned was scant, and much effort would be needed to bring out the extent of its mushroom resources.

Another centre of work in the northern Indian plains has been at the National Botanical Research Institute, Lucknow. Pathak and Gupta (1979) reported 58 species of agarics from the Lucknow area distributed among 25 genera. Prominent genera were: *Agaricus*, *Amanita*, *Chlorophyllum*, *Coprinus*, *Macrolepiota*, *Pleurotus*, *Termitomyces* and *Volvariella*. Earlier, Pathak *et al.* (1978) recorded a total of 13 species of *Volvariella* from India.

Macrofungi in Bengal have been studied by Professor R.P. Purkayastha and Professor N. Samajpati, both working in the Botany Department, University of Calcutta. Purkayastha devoted attention to wild edible mushrooms of the region and succeeded in cultivating one of them, *Calocybe indica* Purkayastha & Chandra. Purkayastha and Chandra (1976, 1985) compiled lists of Indian edible mushrooms which included 283 species of larger fungi.

Rajasthan

Rajasthan is the second largest state of India and represents 10% of the land area of the country. However, about 57% of the state consists of the great Thar desert (Doshi and Sharma, 1997), which has been designated as one of the biosphere reserves and, as a representative of the desert ecosystem in India, is especially important from the conservation angle.

An intensive survey of wild mushrooms was conducted throughout the state by A. Doshi working at the Department of Plant Pathology, Rajasthan College of Agriculture for 8 years (1989–1996). Doshi and Sharma (1997) provided a detailed list of macrofungi occurring in the region with mycoecological notes. A total of 173 species belonging to 95 genera was recorded from the area.

Most genera (18) were gasteromycetes or aphyllophoroid taxa (17). Special mention should be made of two edible gasteromycetes, *Phellorinia inquinans* Berk. and *Podaxis pistillaris*, tonnes of which can be collected from desert areas. *P. inquinans* is associated with sand dunes in the area (Singh, 1994).

Discussion

The foregoing account has shown that the mycological resources of the country are far from fully investigated. Horak (see Lakhanpal, 1995) also pointed out that, considering ecological niches, the Himalayas are still mycologically little explored. Conservation measures, however, can be planned only after widespread recording, mapping and studies on changes in the mycobiota of the Indian subcontinent. The first step in this direction was taken when Dr M.S. Swaminathan (President of WWF–India) sanctioned the preparation of a project report: *Conservation of Mushroom Resources in India* (Kaul, 1992). This report, besides cataloguing the mushroom resources of the country, presented a plan of action for which Kaul (1993) provided the salient features. Unfortunately, no progress has been made to date. It is hoped that new initiatives taken with the commissioning of the Advanced Centre of Biosystematics (Microbes and Invertebrates) will bear fruit in years to come, as it will act as a nodal agency for the entire country.

Hawksworth (1992) emphasized the role of ectomycorrhiza as bioindicators and monitors of ecosystem health. Watling and Abraham (1992), reporting on ectomycorrhizal fungi of Kashmir, recorded that out of 175 species of agarics and clavarioid fungi in Kashmir, 77 were suspected of being mycorrhizal and were also found elsewhere in India. Lichens, too, have been found to be promising indicator species (Hawksworth and Rose, 1976), and it is essential that this group is not neglected in conservation studies. India is reported to contain 1600 species of lichens and Patwardhan (1983) provided a list of rare and endemic species of the Western Ghats.

Tribal involvement is also an important aspect of the conservation of mycological resources in India. Nearly 450 tribal communities constitute about 6% of the country's total population of > 60 million. They possess intimate knowledge of the mushroom resources of their area. Subramanian (1982) dwelt on the urgency of the study, as this information could be permanently lost with the extinction of these tribes.

Few attempts have been made to link the Indian mycota with those of other countries. Abraham (1991) in an overview of the Kashmir mycota maintained that some links with those of Europe and North America were apparent, and Natarajan (1995) considered that mycological recording in the last two decades revealed a lack of similarity between the agaric mycobiota of Tamil Nadu, Karnataka and Andhra Pradesh and Sri Lanka, although Sri Lanka is geographically similarly situated. It has more resemblance to that found in East

Africa and South America. It should be mentioned here that, as opposed to the Indian subcontinent, the agarics of Sri Lanka have been extensively studied since 1871, and as many as 433 species were enumerated as early as 1875 (see Natarajan, 1995).

Watling (1978) has discussed the subject in detail. He maintained that various elements expected in the Indian macromycota could be placed in four categories: (i) cosmopolitan species; (ii) possible South-eastern Asiatic elements; (iii) possible Mediterranean–European elements; and (iv) eastern Asiatic elements (Indo-Chinese).

The gamut of agaricoid species present in India has also been influenced by the replacement of natural forests by exotic trees; for example conifers, eucalypts and *Casuarina* in the hills of southern India. Introduced fungi, for example *Amanita muscaria* (L.: Fr.) J.D. Hook., have been brought in with such exotic tree species. These endemics cause identification problems due to the paucity of available mycologists in India and neighbouring countries.

Watling (1978), when outlining a fruitful future research programme for the study of agarics in India, made special mention of an analysis of a possible connection between the agaric communities of the Malagasy Republic and the records from Sri Lanka and southern India, and secondly of a survey of pockets of relict rainforest vegetation before they disappear. Cooperation with other countries would be necessary for investigations of this type of mycogeography.

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